KEY CONCEPT

4.3 The transfer of energy as heat can be controlled.

BEFORE, you learned

- Temperature is the average amount of kinetic energy of particles in an object
- Heat is the flow of energy from warmer objects to cooler objects

NOW, you will learn

- How energy is transferred through heat
- How materials are used to control the transfer of energy through heat

VOCABULARY

conduction p. 117
conductor p. 117
insulator p. 117
convection p. 118
radiation p. 119

EXPLORE Conduction

How can you observe a flow of energy?

PROCEDURE

1. Fill the large beaker halfway with hot tap water. Fill the small beaker halfway with cold water. Place a thermometer in each beaker. Record the temperature of the water in each beaker.
2. Without removing the water in either beaker, place the small beaker inside the large beaker. Record the temperature in each beaker every 30 seconds for 2 minutes.

MATERIALS

- 500 mL beaker
- hot tap water
- 200 mL beaker
- cold water
- 2 thermometers
- stopwatch

WHAT DO YOU THINK?

- How did the water temperature in each beaker change?
- In which direction did energy flow? How do you know?

Energy moves as heat in three ways.

NOTE-TAKING STRATEGY
Main idea and detail notes would be a useful strategy for taking notes on how heat transfers energy.

Think about what you do to keep warm on a cold day. You may wear several layers of clothing, sit next to a heater, or avoid drafty windows. On a hot day, you may wear light clothing and sit in the shade of a tree. In all of these situations, you are trying to control the transfer of energy between yourself and your surroundings.

Recall that heat is always a transfer of energy from objects at a higher temperature to objects at a lower temperature. How does energy get transferred from a warmer object to a cooler one? There are three different ways in which this transfer of energy can occur—by conduction, convection, and radiation. So, in trying to control heat, it is necessary to control conduction, convection, and radiation.

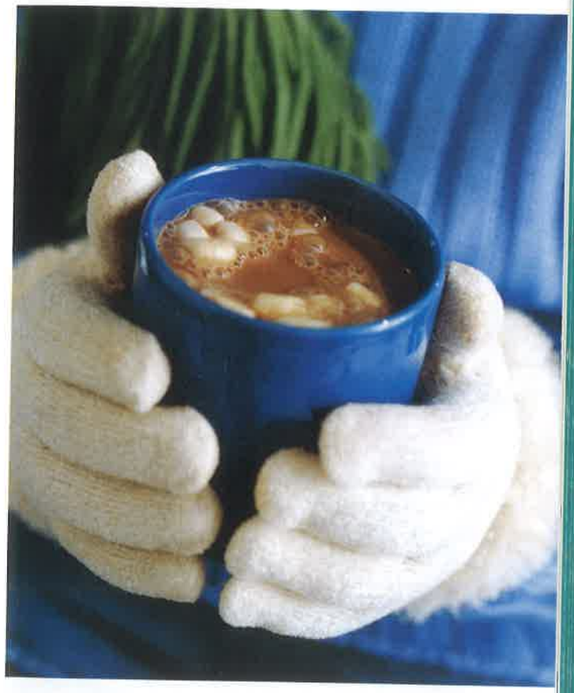
Conduction

One way in which energy is transferred as heat is through direct contact between objects. **Conduction** is the process that moves energy from one object to another when they are touching physically. If you have ever picked up a bowl of hot soup, you have experienced conduction.

VOCABULARY
Remember to make a description wheel diagram for *conduction* and other vocabulary terms.

Conduction occurs any time that objects at different temperatures come into contact with each other. The average kinetic energy of particles in the warmer object is greater than that of the particles in the cooler object. When particles of the objects collide, some of the kinetic energy of the particles in the warmer object is transferred to the cooler object. As long as the objects are in contact, conduction continues until the temperatures of the objects are equal.

Conduction can also occur within a single object. In this case, energy is transferred from the warmer part of the object to the cooler part of the object by heat. Suppose you put a metal spoon into a cup of hot cocoa. Energy will be conducted from the warm end of the spoon to the cool end until the temperature of the entire spoon is the same.



Conduction transfers energy from the cocoa to the mug to the person's hands.

Some materials transfer the kinetic energy of particles better than others. **Conductors** are materials that transfer energy easily. Often, conductors also have a low specific heat. For example, metals are typically good conductors. You know that when one end of a metal object gets hot, the other end quickly becomes hot as well. Consider pots or pans that have metal handles. A metal handle becomes too hot to touch soon after the pan is placed on a stove that has been turned on.

Other materials, called **insulators,** are poor conductors. Insulators often have high specific heats. Some examples of insulators are wood, paper, and plastic foam. In fact, plastic foam is a good insulator because it contains many small spaces that are filled with air. A plastic foam cup will not easily transfer energy by conduction. As a result, plastic foam is often used to keep cold drinks cold or hot drinks hot. Think about the pan handle mentioned above. Often, the handle is made of a material that is an insulator, such as wood or plastic. Although a wood or plastic handle will get hot when the pan is on a stove, it takes a much longer time for wood or plastic to get hot as compared to a metal handle.

CHECK YOUR READING How are conductors and insulators different?

Convection

REMINDER
Density = $\frac{\text{mass}}{\text{Volume}}$

Energy can also be transferred through the movement of gases or liquids. **Convection** is the process that transfers energy by the movement of large numbers of particles in the same direction within a liquid or gas. In most substances, as the kinetic energy of particles increases, the particles spread out over a larger area. An increased distance between particles causes a decrease in the density of the substance. Convection occurs when a cooler, denser mass of the gas or liquid replaces a warmer, less dense mass of the gas or liquid by pushing it upward.

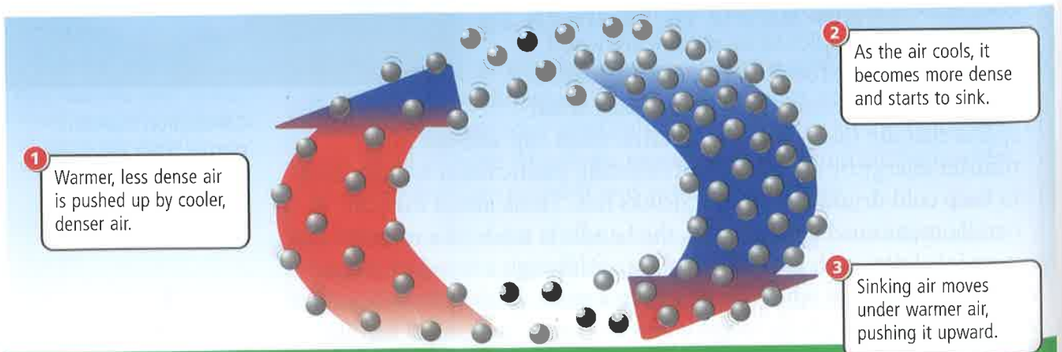
Convection is a cycle in nature responsible for most winds and ocean currents. When the temperature of a region of air increases, the particles in the air spread out and the air becomes less dense.

READING TiP
As you read about the cycle that occurs during convection, follow the steps in the illustration below.

1. Cooler, denser air flows in underneath the warmer, less dense air, and pushes the warmer air upward.
2. When this air cools, it becomes more dense than the warmer air beneath it.
3. The cooled air sinks and moves under the warmer air.

Convection in liquids is similar. Warm water is less dense than cold water, so the warm water is pushed upward as cooler, denser water moves underneath. When the warm water that has been pushed up cools, its density increases. The cycle continues when this more dense water sinks, pushing warmer water up again.

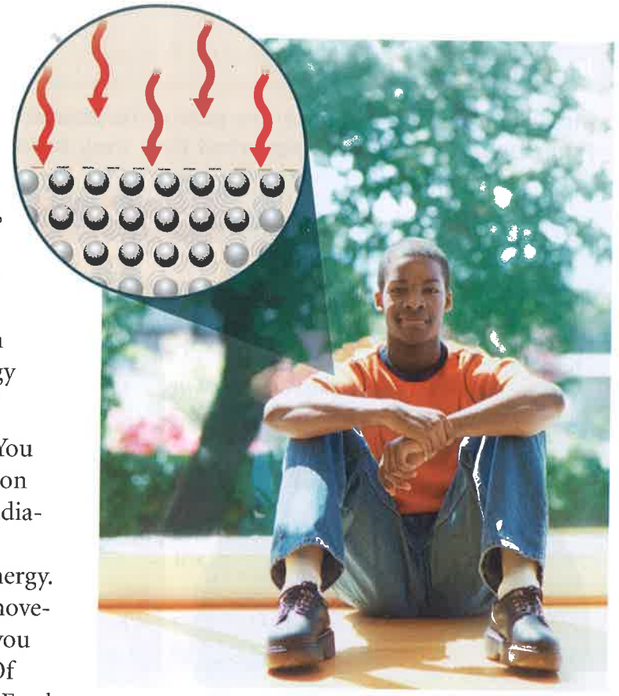
Recall that a large body of water, such as Lake Michigan, influences the temperature of the land nearby. This effect is due to convection. During the spring and early summer, the lake is cool and warms more slowly than the land. The air above the land gets warmer than the air over the water. The warmer air above the land is less dense than the cooler air above the water. The cooler, denser air moves onshore and pushes the warmer air up. The result is a cooling breeze from the lake.



READING VISUALS Where in the cycle is air more dense? less dense?

Radiation

Radiation is another way in which energy can be transferred from one place to another. **Radiation** is energy that travels as electromagnetic waves, which include visible light, microwaves, and infrared (IHN-fruh-REHD) light. The Sun is the most significant source of radiation that you experience on a daily basis. However, all objects—even you—emit radiation and release energy to their surroundings.



When radiation from the Sun is absorbed, energy is transferred through heat.

Consider radiation from the Sun. You can feel radiation as heat when radiation from the Sun warms your skin. The radiation emitted from the Sun strikes the particles in your body and transfers energy. This transfer of energy increases the movement of particles in your skin, which you detect as an increase in temperature. Of course, you are not the only object on Earth that absorbs the Sun's radiation. Everything—from air to concrete sidewalks—absorbs radiation that increases particle motion and produces an increase in temperature.

When radiation is emitted from one object and then is absorbed by another, the result is often a transfer of energy through heat. Like both conduction and convection, radiation can transfer energy from warmer to cooler objects. However, radiation differs from conduction and convection in a very significant way. Radiation can travel through empty space, as it does when it moves from the Sun to Earth. If this were not the case, radiation from the Sun would have no effect on Earth.

SIMULATION
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Identify examples of conduction, convection, or radiation.

CHECK YOUR READING How does radiation transfer energy?

Different materials are used to control the transfer of energy.

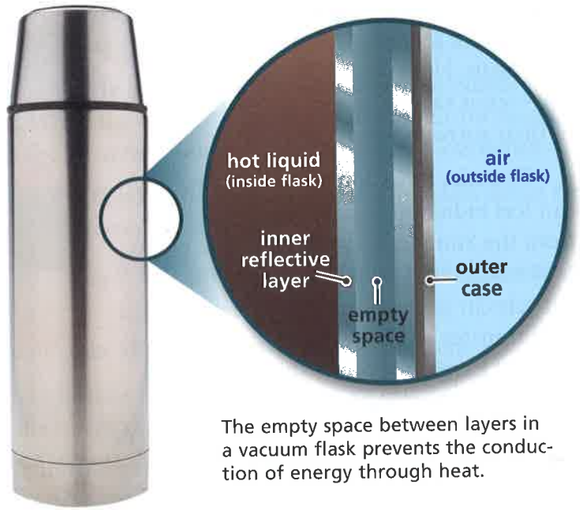
Energy is always being transferred between objects at different temperatures. It is often important to slow this movement of energy. For example, if energy were always transferred quickly and efficiently through heat, it would not be possible to keep a building warm during a cold day or to keep cocoa hot in a thermos.

Insulation

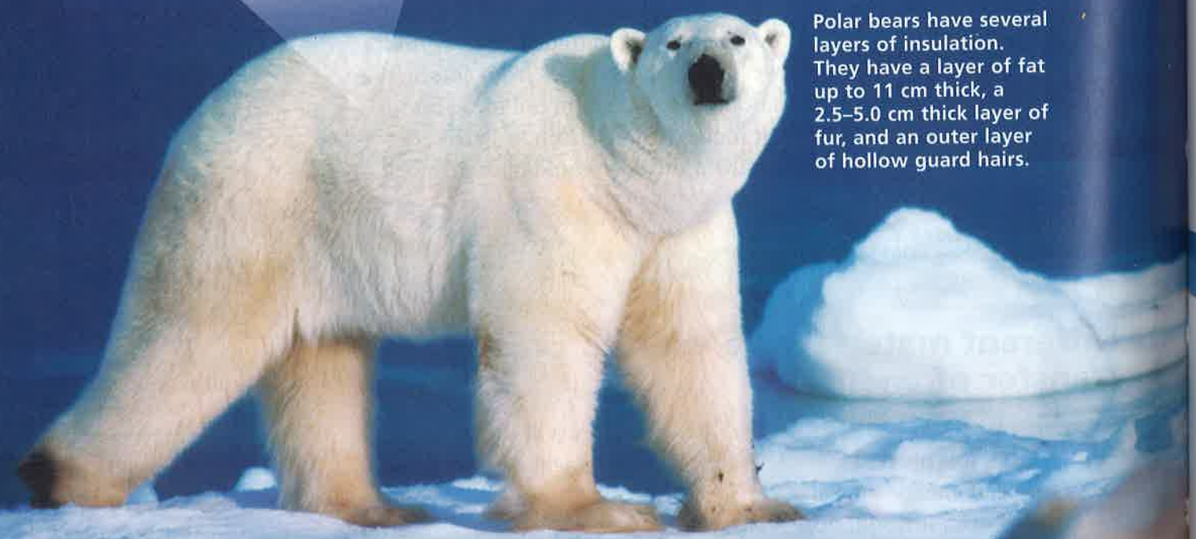
Insulators used by people are similar to insulators in nature. Polar bears are so well insulated that they tend to overheat.

The polar bear's hollow guard hair is an effective insulator because air inside the hair does not easily conduct energy.

Vacuum Flask



The empty space between layers in a vacuum flask prevents the conduction of energy through heat.



Polar bears have several layers of insulation. They have a layer of fat up to 11 cm thick, a 2.5–5.0 cm thick layer of fur, and an outer layer of hollow guard hairs.

READING VISUALS How is the polar bear's hollow hair similar to the empty space in a vacuum flask? How is it different?

Insulators are used to control and slow the transfer of energy from warmer objects to cooler objects because they are poor conductors of energy. You can think of an insulator as a material that keeps cold things cold or hot things hot.

Sometimes people say that insulation "keeps out the cold." An insulator actually works by trapping energy. During the winter, you use insulators such as wool to slow the loss of your body heat to cold air. The wool traps air against your body, and because both air and wool are poor conductors, you lose body heat at a slower rate. Fiberglass insulation in the outer walls of a building works in the same way. The fiberglass slows the movement of energy from a building to the outside during cold weather, and it slows the movement of energy into the building during hot weather.

A vacuum flask, or thermos, works in a slightly different way to keep liquids either hot or cold. Between two layers of the flask is an empty space. This space prevents conduction between the inside and outside walls of the flask. Also, the inside of the flask is covered with a shiny material that reflects much of the radiation that strikes it. This prevents radiation from either entering or leaving the flask.

Insulators that people use are often very similar to insulators in nature. Look at the photograph of the polar bear on page 120. Because of the arctic environment in which the polar bear lives, it needs several different types of insulation. The polar bear's fur helps to trap a layer of air against its body to keep warmth inside. Polar bears also have guard hairs that extend beyond the fur. These guard hairs are hollow and contain air. Because air is a poor conductor, the bear's body heat is not easily released into the air.

CHECK YOUR READING How does insulation keep a building warm?

4.3 Review

KEY CONCEPTS

1. What are three ways in which energy can be transferred through heat? Provide an example of each.
2. Explain how convection is a cycle in nature.
3. Describe how an insulator can slow a transfer of energy.

CRITICAL THINKING

4. **Compare and Contrast** Describe the similarities and differences among conduction, convection, and radiation.
5. **Synthesize** Do you think solids can undergo convection? Why or why not? Explain.

CHALLENGE

6. **Infer** During the day, wind often blows from a body of water to the land. What do you think would happen at night? Explain.

4 Chapter Review

the BIG idea

Heat is a flow of energy due to temperature differences.

CONTENT REVIEW
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KEY CONCEPTS SUMMARY

4.1 Temperature depends on particle movement.

- All particles in matter have kinetic energy.
- Temperature is the measurement of the average kinetic energy of particles in an object.
- Temperature is commonly measured on the Fahrenheit or Celsius scales.

Particles in a warmer substance have a greater average kinetic energy than particles in a cooler substance.

VOCABULARY
kinetic theory of matter p. 104
temperature p. 105
degree p. 106
thermometer p. 107

4.2 Energy flows from warmer to cooler objects.

- Heat is a transfer of energy from an object at a higher temperature to an object at a lower temperature.
- Different materials require different amounts of energy to change temperature.

Energy is transferred from the warmer lemonade to the cold ice through heat.

VOCABULARY
heat p. 110
thermal energy p. 111
calorie p. 112
joule p. 112
specific heat p. 113

4.3 The transfer of energy as heat can be controlled.

- Energy can be transferred by conduction, convection, and radiation.
- Different materials are used to control the transfer of energy.

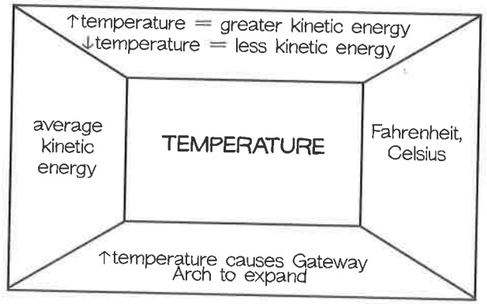
Types of Energy Transfer

Conduction	Convection	Radiation
• Energy transferred by direct contact • Energy flows directly from warmer object to cooler object • Can occur within one object • Continues until object temperatures are equal	• Occurs in gases and liquids • Movement of large number of particles in same direction • Occurs due to difference in density • Cycle occurs while temperature differences exist	• Energy transferred by electromagnetic waves such as light, microwaves, and infrared radiation • All objects radiate energy • Can transfer energy through empty space

VOCABULARY
conduction p. 117
conductor p. 117
insulator p. 117
convection p. 118
radiation p. 119

Reviewing Vocabulary

Make a frame for each of the vocabulary terms listed below. Write the term in the center. Decide what information to frame it with. Use definitions, examples, descriptions, parts, or pictures.



1. kinetic theory of matter
2. heat
3. thermal energy
4. conduction
5. convection
6. radiation

In two or three sentences, describe how the terms in the following pairs are related to each other. Underline each term in your answers.

7. calorie, joule

8. conductor, insulator

Reviewing Key Concepts

Multiple Choice *Choose the letter of the best answer.*

9. What is the zero point in the Celsius scale?
- **a.** the freezing point of pure water
- **b.** the boiling point of pure water
- **c.** the freezing point of mercury
- **d.** the boiling point of alcohol

10. Energy is always transferred through heat from?
- **a.** an object with a lower specific heat to one with a higher specific heat
- **b.** a cooler object to a warmer object
- **c.** an object with a higher specific heat to one with a lower specific heat
- **d.** a warmer object to a cooler object

11. The average kinetic energy of particles in an object can be measured by its
- **a.** heat
- **b.** thermal energy
- **c.** calories
- **d.** temperature

12. How is energy transferred by convection?
- **a.** by direct contact between objects
- **b.** by electromagnetic waves
- **c.** by movement of groups of particles in gases or liquids
- **d.** by movement of groups of particles in solid objects

13. The total kinetic energy of particles in an object is
- **a.** heat
- **b.** thermal energy
- **c.** calories
- **d.** temperature

14. Water requires more energy than an equal mass of iron for its temperature to increase by a given amount because water has a greater
- **a.** thermal energy
- **b.** specific heat
- **c.** temperature
- **d.** kinetic energy

15. Energy from the Sun travels to Earth through which process?
- **a.** temperature
- **b.** conduction
- **c.** radiation
- **d.** convection

16. An insulator keeps a home warm by
- **a.** slowing the transfer of cold particles from outside to inside
- **b.** increasing the specific heat of the air inside
- **c.** slowing the transfer of energy from inside to outside
- **d.** increasing the thermal energy of the walls

17. Conduction is the transfer of energy from a warmer object to a cooler object through
- **a.** a vacuum
- **b.** a gas
- **c.** direct contact
- **d.** empty space

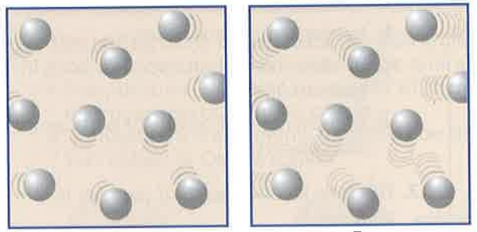
Short Answer *Write a short answer to each question.*

18. How are kinetic energy and temperature related to each other?

19. What is the difference between heat and temperature?

Thinking Critically

The illustrations below show particle movement in a substance at two different temperatures. Use the illustrations to answer the next four questions.



A B

20. **OBSERVE** Which illustration represents the substance when it is at a higher temperature? Explain.

21. **PREDICT** What would happen to the particles in illustration A if the substance were chilled? What would happen if the particles in illustration B were warmed?

22. **PREDICT** If energy is transferred from one of the substances to the other through heat, in which direction would the energy flow (from A to B, or from B to A)? Why?

23. **COMMUNICATE** Suppose energy is transferred from one of the substances to the other through heat. Draw a sketch that shows what the particles of both substances would look like when the transfer of energy is complete. Explain.

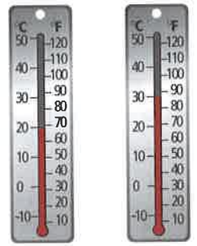
24. **COMPARE AND CONTRAST** How are conduction and convection similar? How are they different?

25. **DRAW CONCLUSIONS** Suppose you are outdoors on a hot day and you move into the shade of a tree. Which form of energy transfer are you avoiding? Which type of energy transfer are you still feeling? Explain.

26. **COMMUNICATE** Draw a sketch that shows how convection occurs in a liquid. Label the sketch to indicate how the process occurs in a cycle.

Using Math Skills in Science

Use the illustrations of the two thermometers below to answer the next four questions.



A B

27. How much of a change in temperature occurred between A and B in the Fahrenheit scale?

28. Suppose the temperatures were measured in 10 g of water. How much energy, in calories, would have been added to cause that increase in temperature? (**Hint:** 1 calorie raises the temperature of 1 g of water by 1°C.)

29. Again, suppose the temperatures shown above were measured in 10 g of water. How much energy, in joules, would have been added? (**Hint:** 1 calorie = 4.18 joules.)

30. Suppose that the temperatures were measured for 10 g of iron. How much energy, in joules, would have been added to cause the increase in temperature? (**Hint:** see graph on p. 113.)

the BIG idea

31. **ANALYZE** Look back at the photograph and the question on pages 100 and 101. How has your understanding of temperature and heat changed after reading the chapter?

32. **COMMUNICATE** Explain the kinetic theory of matter in your own words. What, if anything, about the kinetic theory of matter surprised you?

UNIT PROJECTS

Evaluate all the data, results, and information from your project folder. Prepare to present your project.

Standardized Test Practice

For practice on your state test, go to . . .
TEST PRACTICE
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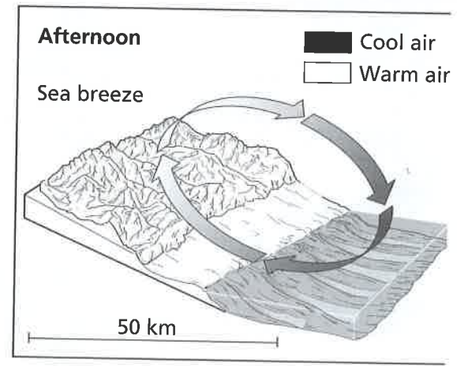
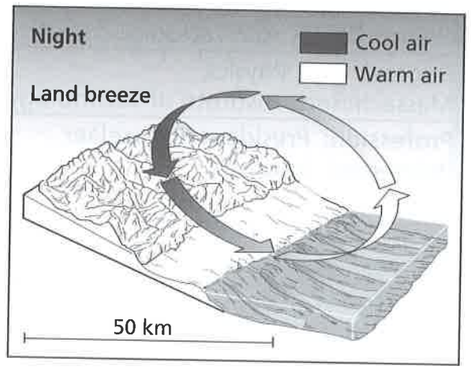
Interpreting Diagrams

The diagrams below illustrate the process that occurs in sea and land breezes.





Use the diagrams above to answer the next five questions.

1. What happens during the day?
- **a.** Cool air from the land flows out to sea.
- **b.** Warm air from the land flows out to sea close to sea level.
- **c.** Cool air from the sea flows to the land.
- **d.** Warm air from the sea flows to the land.

2. What characteristic of large bodies of water explains why the seawater is cooler than the land in the hot afternoon sun?
- **a.** Water is liquid while the land is solid.
- **b.** Water has a higher specific heat than land.
- **c.** Land is a better insulator than water.
- **d.** Land has a higher specific heat than water.

3. What process causes the warm air to move upward over the land during the day?
- **a.** convection
- **b.** condensation
- **c.** evaporation
- **d.** radiation

4. Warm air is pushed upwards by cooler air during convection because the warm air
- **a.** is more dense
- **b.** has more mass
- **c.** is less dense
- **d.** has less mass

5. About how far over water does this land breeze extend?
- **a.** 1 kilometer
- **b.** 10 kilometers
- **c.** 25 kilometers
- **d.** 50 kilometers

Extended Response

Answer the two questions below in detail. Include some of the terms from the word box on the right. Underline each term that you use in your answer.

boiling point	heat	specific heat
conduction	freezing point	zero point

6. What are the differences between the Fahrenheit and Celsius temperature scales? Which one is used in science? Why might this be the case?

7. Suppose you place three spoons—one metal, one plastic, and one wood—into a cup filled with hot water. The bowl end of the spoon is inside the cup and the handle is sticking up into the air. On each handle, you place a bead, held to the spoon by a dab of margarine. From which spoon will the bead fall first, and why?